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Operational Psychology Countermeasures During the Lunar-Mars Life Support Test Project

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SUMMARY

The Crew and Thermal Systems Division at the NASA Johnson Space Center conducted a series of human-rated tests designed to advance technology in closed life support systems. As the duration of these tests lengthened, the psychological factors associated with placing humans in these environments became increasingly salient to successful mission completion. A number of psychological activities were conducted to ensure successful operations and protect crewmember well-being, including individual crewmember selection, crew composition, training and preparation, family inclusion, educational briefings, in-mission tracking, operational interventions, and postmission repatriation. This article describes these activities, the rationale behind their design, the similarities and differences to techniques utilized for space flight, and considerations related to designing psychological countermeasures for confined environments. In addition to testing physical and engineering systems, the chambers studies series functioned as an effective test bed for developing operational concepts and countermeasures for extended space missions.

Introduction

Between 1995 and 1998, the Crew and Thermal Systems Division at the NASA Johnson Space Center conducted a series of ground-based tests designed to advance technology in closed life support systems. The regenerative technology was tested with human crews in four tests, or phases, whose objective was to ultimately produce equipment and processes that could be incorporated into a variety of lunar, Martian, and low-Earth orbit stations and vehicles. The four tests were termed Phase I (15 days, one person), Phase II (30 days, four persons), Phase IIa (60 days, four persons), and Phase III (91 days, four persons). The crewmembers performed a number of technical and research tasks in the areas of engineering, station maintenance, medicine, and life science. In addition, they had exercise, housekeeping,

media events, educational outreach, and other duties related to the conduct of high-profile confinement missions. There are many sources for detailed descriptions of the physical living environment, its phases, physical layout, engineering, accommodations, and schedules, including Barta and Dominick (1), Laws and Foerg (2), Ming et al. (3), and Meyers et al (4).

When considering any mission within an extreme or confined environment, there are a number of psychological issues that the planner must address. Obviously, as the severity of the environmental, work, or personnel factors increases, or as the importance of goal attainment increases, it becomes more critical that the psychological issues involving the crewmembers are dealt with in a proactive manner. Over time, the duration and complexity of the LMLSTP phases increased, and the psychological aspects associated with maintaining crew health, well-being, productivity, and team functioning became increasingly salient.

A number of psychological activities and countermeasures were conducted to ensure successful completion of the phases and to protect the crewmembers' psychological health and well-being. These operational activities, including crew selection, training and preparation, family inclusion, control room team management, in-mission tracking, management consultation, in-mission interventions, postmission debriefings, and so forth, differed from the psychological research conducted during some of the phases. The psychological countermeasures were implemented specifically and solely to assure that the objectives of the tests, including psychological health and readiness objectives, would be achieved. The team that designed and provided the psychological countermeasures had previous experience doing so for missions in other ground-based, underwater, and space environments.

The purpose of this chapter is to give an overview of the psychological countermeasures designed for the closed-loop living environment, and some of the operational considerations that steered their implementation. Although all of the issues that arose during a particular phase are not included here, a sampling of issues is discussed. A more detailed discussion of the driving factors behind the design of psychological countermeasures can be found elsewhere (5).

Early Assumptions

Like all human missions, the advanced human life support enclosed system study final report had its own distinctive configuration and set of constraints that shaped the conduct of its missions. These included:

1. The division and project management that conducted the studies had never before conducted or participated in a human-rated confinement project.

2. The project would consist of multiple tests of increasing complexity and duration.

3. It would be necessary to place system experts, who were inexperienced in confined operations, inside the chambers in order to repair and maintain the systems.

4. There was interest within the life science research community in using the series to perform non-engineering studies pertaining to extended confinement.

5. Everyone within the organization was highly motivated to have a successful test series, and management was aware of the importance of psychological factors.

Phase I

During the very early planning stages of the series, the project management requested general psychological requirements. Those that were submitted covered a wide range of individual, team, and environmental topics, such as the necessity for meaningful work versus "make work," reasonable work-rest schedules, exercise capability, several types of communication capabilities, a systematic procedure for psychologically selecting and preparing participants, sleep protection, and basic habitability (e.g., privacy, leisure resources). These basic guidelines were incorporated into the overall study design.

The 15-day, one-person test was the first to be conducted. The simplicity of this phase did not require a large number of countermeasures from the psychological team. Due to its relatively short duration, this test was not expected to be as psychologically challenging as the longer, multi-person tests. Its duration was similar to that of a Space Shuttle mission, although it only involved one person. This latter fact was the only potential source of concern. However, it was offset by several beneficial factors:

1. Basic psychological requirements had been applied to accommodate fundamental psychological needs inside the chamber.

2. Tasks were straightforward and meaningful.

3. The participant was a Crew and Thermal Systems Division engineer who had been highly involved in the development of the regenerative life support systems being tested.

4. The outside control team was small and was composed of friends and colleagues of the participant inside the chamber.

5. The duration of the test was short.

6. The participant possessed the necessary personality characteristics and motivational set needed to cope with the solo conditions of the test.

Table 3.5-1 *Psychological Countermeasures*

	Phase I (15 Days)	**Phase II** (30 Days)	**Phase IIA** (60 Days)	**Phase III** (91 Days)
Basic Operating Requirements	X	X	X	X
Selection (select out)				
Psychological testing	X	X	X	X
Structured interview	X	X	X	X
Selection (select in)				
Psychological testing		X	X	X
Structured interview		X	X	X
Reference interviews				X
Crew Assembly				
Psychological testing		X	X	X
Situational assessments				X
Peer evaluations				X
Staffing w/committee		X	X	X
Training and Preparation				
1st crew briefing with crew-psyc. basic factors of long-duration confinement		X	X	X
Team building			X	X
Lessons Learned briefing		X	X	X
Confined team operations/Leadership				X
Individual Psyc. Planning		X	X	X
Advanced Psyc. Factors/ Lessons Learned Briefing			X	X
Effective communication training for control room (CR) personnel			X	X

Table 3.5-1 continued *Psychological Countermeasures*

	Phase I (15 Days)	**Phase II** (30 Days)	**Phase IIA** (60 Days)	**Phase III** (90 Days)
Control team/crew resource management training			X	
1st family meeting			X	X
2nd family meeting			X	X
3rd family meeting				X
4th family meeting				X
Lessons Learned/Psyc. Factors briefing with project management				X
Individual crewmember prep meeting				X
Monitoring				
Individual and group psyc conferences w/crew	X	X	X	X
Individual and group psyc conferences w/control room team			X	X
Individual and group psyc conferences w/families		X	X	X
Posttest				
1st debrief (~3 days post test)		X	X	X
2nd debrief (~14 days post test)		X	X	X

As shown in Table 3.5-1, the only measures taken for this phase by the psychological team were basic requirements, selection, and monitoring. In Phase I, selection only consisted of a review of the participant's ability to fulfill the mission, and monitoring was accomplished through informal visits to the chamber/control team to see that things were proceeding well. With the exception of providing the basic psychological requirements, this phase could have been accomplished successfully without any involvement of psychology. The human accommodations incorporated into this first test were rudimentary but sufficient for the duration. Later missions benefited through input from professionals in the physical design and accommodations area.

It is important to note that the motivational set of the Phase I participant was particularly high in part because he had been involved in developing many of the life support systems that were being tested in the closed facility. In confinement situations, it is very important for the participants to have meaningful work to perform; situations in which "make work," too little work, or meaningless tasks are scheduled will have a demoralizing effect on the participant. Previous U.S. experience on board the Mir station, as well as in other confined, ground-based settings, has highlighted this fact. Conversely, when someone is very interested and heavily invested in a task, motivation is high to endure any difficulties to see it through to the end. This latter case was the situation with all of the crewmembers in the enclosed system study series.

Phase II

This test was a four-person, 30-day test. Although still relatively brief from a duration perspective, the project was moving toward greater complexity by using four participants, moving to a larger chamber, adding additional hardware maintenance tasks to the internal workload, and gradually extending the duration. From a psychologist's perspective, this cautious extension was a wise decision, because the organization was new to crewed test beds and had a number of management and logistical lessons yet to learn. There was not only the matter of learning to structure and manage the activities of the confined participants, but also the job of learning how to staff and structure the activities of the outside control room (CR) and their relationship to the inside team.

In an early planning meeting between project management and the psychology team, several decisions were made that would affect not only the course of Phase II but of subsequent phases as well. These decisions addressed programmatic design issues of a psychological nature that, in the past, had direct effects on the success of other confinement tests and analogous missions. Among the key decisions were:

1. To promote a shift from a "test mentality" to a "mission mentality." This involved the organization as a whole adopting a somewhat different view of what they had been doing for years. Instead of simply providing a metabolic load for the system, the essential, multifaceted role of the human inside the closed environment was recognized. The addition of a few medical and life science objectives resulted in a more diverse set of test objectives to be carried out. Education outreach objectives were increased over Phase I, and methods similar to those used in space missions were utilized. Hence, instead of "subjects," the participants would be called "crewmembers" and comprise a cohesive "crew." Distinct job roles for each of the crewmembers would be identified and a crew "commander" would be formally designated. Together, the crew, the control room (CR) personnel, and project management were tasked with carrying out the ground-based "mission."

The establishment of a crew identity and mission mentality was especially important to the psychology team. Crew psychological health, well-being, and productivity are greatly facilitated by the motivation and focus that is derived from a mission context. This is particularly helpful when mission durations lengthen, and a greater burden is placed on individual and team coping strategies. In addition, the mission model offers a template from which the organization can draw a number of solutions to issues such as control room staffing schedules, management of human research data, and so forth.

2. To use the early, relatively brief phases to create a cadre of experienced crew members for later, more difficult phases and follow-on programs. It was anticipated that the later phases would be considerably longer and that programs which followed LMLSTP might be far more complex and psychologically challenging. It was recommended that the organization pursue a "farm club" approach with respect to crew selection; the objective being to expose as many engineers as possible to the briefer confinements before tackling the tougher missions. This would result in a local group that was operationally and psychologically experienced from which to draw crew members. The farm club approach requires that the early phases not be overly difficult and that they be an explicit part of building a potential crew member pool for later projects.

3. To compose crews that are diverse in gender and experience but which represent all of the essential technical skills needed inside the chamber. There are no magic numbers that comprise the "best" crew size or the "best" gender mix. The principal driver for these issues is ensuring that you have the necessary technical skills and minimum number of people inside the chamber to most effectively achieve the mission objectives. However, duration plays a role here as well. Considering the limited scope of this article, suffice it to say that it was recommended that mixed-gender crews be used.

As Table 3.5-1 indicates, the psychological countermeasures for Phase II were increased over those for Phase I, but were still at a relatively low level due to the brief duration. As mentioned above, the development of the mission context was the single most effective and far-reaching psychological act. After that, psychological selection activities had the greatest impact.

In all types of missions (e.g., space, military, polar, ground studies, etc.), many diverse factors influence who is actually assigned to a mission, and psychological information is only one part of the overall selection process. However, within that part, individuals are sought who are psychologically suited for the target mission and who work well together as a team. In general, the determination of individual suitability and team compatibility for long-duration missions is a systematic, multi-

stage process that involves psychological testing, structured screening interviews, structured reference interviews, skill-based training and selection exercises, sociometric ratings, formal briefings, individual strategy sessions, and other techniques. The specific techniques are chosen and adapted according to the characteristics of the target mission. Similarly, the psychological training and preparation of the individual crewmembers, the crew, the CR personnel, and the crew families varies according to the demands that the target mission is expected to place on them. In-mission monitoring and support procedures, as well as postmission repatriation and tracking activities, also must be tailored to the individual mission.

For Phase II, selection and compatibility were determined by an abbreviated version of psychological testing and through a structured interview, which was a combination of two screening ("select-out") and suitability ("select-in") interviews used for selecting astronauts for extended missions. The select-out testing and interview process addressed the clinical psychological fitness of potential candidates, and the select-in testing and interview process addressed the psychological suitability of each candidate for the target mission. The criteria were scaled to a level appropriate for a ground-based test bed of 30 days' duration. Training and preparation consisted of two crew briefings and an individual planning session with each crewmember, in which lessons learned from previous similar missions were passed along, potential issues were identified, and personal and team strategies were created and reviewed. As in preparation for space missions, the lessons, issues, and strategies that were covered were divided into three categories, specifically those that applied to: 1) the individual crewmember, including family issues; 2) the crew as a whole, including leadership; and 3) the wider organization, including management and control room relations.

This cautious foray into extended, human-rated test beds was successful from a psychological perspective as well as from a mission perspective. As anticipated, the team functioned very well as a unit, and the individual crewmembers felt that they could easily stay in the chamber much longer. As usual, the project analyzed the mission for lessons that could be applied to the next mission. One of these was the need to further clarify the roles and responsibilities of key individuals within the wider organization and the manner in which these roles interfaced with that of the crew, especially that of the crew commander.

Phase IIa

The next mission extended the duration for a four-person crew to 60 days. The increased psychological demand inherent in this phase necessitated a slightly greater set of countermeasures. A somewhat more stringent version of the selection testing and interviewing process was applied to the individual candidates, and significantly more effort was expended on assembling a compatible crew.

Additionally, activities were added in the areas of preparation of CR personnel and family members. The issues facing CR personnel were significant, because the organization had little experience maintaining a rested external team over an extended period of time. The psychological team passed along CR lessons learned from other environments and promoted three general themes: 1) further inclusion of the CR group as an integral part of the team and acknowledgment of their contribution, 2) mutual understanding of the daily issues facing the crew and the CR groups and strategies for managing that interface, and 3) a reasonable work-rest schedule for individuals in the CR. The organization as a whole was very eager to pursue these themes, because there was a vital, preexisting team spirit and a high tendency toward inclusion in general. During the mission, both of the groups made it clear that they valued the other's continuing efforts.

Similar to the Phase II experience, one of the principal lessons learned from Phase IIa was that the definition of the work roles and responsibilities of key people inside and outside of the chamber must be made clear and specific to an extraordinary degree. This somewhat mitigates the misunderstandings and erroneous assumptions that naturally arise between two interdependent groups that are physically and visually separated. Disconnects and miscommunications of intention between crews and their control rooms can lead to a "we-they" phenomenon that is a classical occurrence in a variety of venues (polar, space, military, etc.). This did not occur in Phase IIa, because both groups consciously worked to lessen the issue.

Beginning with Phase IIa and continuing into Phase III, the crewmembers' families or significant others were brought together before the mission and during the mission for psychological information about the mission, and to create an environment of mutual support between them. In Phase IIa, these informal gatherings occurred over lunch. Inclusion of family members is a powerful crew support method for many reasons, in addition to being a source of strength for the crewmembers' families.

Phase III

With the advent of Phase III, the project had at last reached a mission duration that approached some of the briefer Mir space flights. In addition to increased length, the project included a large number of science experiments or technology demonstration projects from the life sciences. Scientists were interested in various effects of extended confinement, the suitability of specific exercise and nutrition protocols, and a number of habitability, training, and medical issues. From a psychological viewpoint, this increased workload was welcome; with the scientific, hardware maintenance, and education outreach tasks, there would be plenty of opportunity for meaningful work. However, the duration and complexity of the test bed were not trivial, and that warranted the application of more extensive psychological countermeasures.

Selection was more stringent; the criteria were in line with the increased demand on the individual to adapt effectively and to function well as part of a confined team. Individual selection activities were extended to include structured interviews of character references and more extensive reviews of each candidate's history in past work teams. It was essential that the applicant possess the skills to maintain a cohesive crew while still enabling diversity of opinion. The initial process of testing, interviewing, and history review resulted in eight candidates remaining, from which four would be assigned as prime crewmembers and four as back up crewmembers.

At this point, activities were devised that served both psychological training and selection needs. Within the group of eight individuals, some had worked together in the Crew and Thermal Systems Division for years and knew each other very well; some came from outside organizations and were unknown to most of the group. Some had been crewmembers in previous chamber missions, and some had no experience with either confinement or operational environments. The objectives at this stage were to: 1) identify a set of four people who would work well together as a prime crew, 2) prepare all eight individuals to work together in the event that back up crewmembers were rotated in during the mission, 3) provide a means for the eight to get to know each other in problem-solving situations and under conditions of mild stress, and 4) begin to integrate the new people into the Crew and Thermal Systems group that was fielding the mission.

An outdoor challenge course was used to accomplish these selection and team building objectives. An initial series of low-level, physical problem-solving situations was presented to the eight as a group, and the team worked these out as they saw fit. In a subsequent series of high-level traverses and climbs, the group split into pairs and triads to resolve the challenges. Membership in the pairs was rotated, so that people would have a chance to work with each other in a smaller unit. Each situation was debriefed by the group and the psychological team for lessons learned that might apply to the actual Phase III mission, and general information regarding teamwork styles for extended missions was passed along. The most significant benefit of this training, however, was the familiarization and integration of the eight team members with one another.

Following this preparation, the eight team members completed a sociometric form in which each of them gave their input regarding who they would select to be with them on the upcoming mission. This was an opportunity for the crewmembers to express their social preferences and to have their input factored into the crew assembly process. The psychological team combined this input with their own to develop recommendations for crew composition. Ultimately, of the four prime crewmembers that were assigned, two were Crew and Thermal Systems engineers who were crewmembers on previous enclosed system study missions, and two others were scientists with no previous confinement or mission experience. The early integration and sociometric activities would later prove to be a good investment when a prime crewmember had to be swapped out for a back up just prior to mission start.

Once the prime and back up crewmembers were assigned, the psychology team turned its attention to providing sufficient preparation of the crewmembers, their families, the control room, and project management. In some cases, we only provided encouragement and assistance to key people to prepare themselves for the mission, as was the case with meetings to further define job roles and responsibilities and a training workshop for CR personnel. In other cases, we provided direct training. This included more lessons learned briefings for the prime and back up crewmembers, individual planning sessions to discuss potential situations that might arise and to review strategies for dealing with them, information and integration meetings with the families, a training briefing for project management, and a five-day experiential training course on confined team operations for the prime crew.

The Confined Team Operations training was designed to prepare the prime crew in precisely the following areas: 1) confined living and working, 2) integration and organization as a team, and 3) actual mission operations experience. A working underwater station with a topside control and logistics facility was the setting for the week-long training. The crew was provided with a schedule, scientific and station maintenance goals, and crew organization goals that were comparable to those expected on the three-month mission. In addition, the design incorporated a condensation of a number of scenarios and conditions that had arisen on previous enclosed system study missions, or on analogous missions of three months' duration, which had the possibility of arising during their upcoming mission. The prime crew was provided with a blend of didactic, discussion, and hands-on experience regarding living and working in confined settings, leadership and followership, personal adaptation, safety, scheduling and rescheduling, time management, team norms, managing a relationship with the control center, contingency planning, conducting interviews with the media, analogue lessons learned, and other topics related to the upcoming mission. In addition, the designated commander had an opportunity to establish the leadership style that he would use, the entire crew had an opportunity to sort out their roles, and the experienced crewmembers brought the others up to speed on all aspects of the organization, procedures, and points-of-contact among other things.

Approximately one month prior to the start of the Phase III mission, the psychological team held individual meetings with the prime and back up crewmembers to review their readiness for the mission, and to jointly identify any issues that needed to be handled. For the back up crewmembers, the main issue was certainly one of psychological readiness, because it is very typical for back up crewmembers, once prime crew assignments are made, to shift their attention to the demands of their daily jobs rather than the demands of the impending mission. It is not a fault; it is simply a matter of probability and expectation. They reasonably conclude that there is a higher probability that they will be on the outside of the chamber during the mission than on the inside, and it is not easy for a back up crewmember to maintain a state of mental preparedness for something he or she is not likely to do.

Consequently, the individual meetings were, in part, designed to relight the process of mental preparation in the back up crewmember. Approximately two weeks prior to the mission start, the prime crew commander had to be removed from the crew for medical reasons. A back up crewmember was rotated in, and a commander was assigned from the remaining prime crew. This was a major disruption, but it came with some excellent lessons attached.

The tracking of the crew's psychological health and well-being was accomplished through regular visits to the chamber at various times during the work week and on weekends. Of particular interest were aspects of the ongoing mission such as individual workload, technical concerns including failed equipment, the development of threats to the mission completion, or to crew health and well-being, the amount and quality of sleep, significant news from home or work, mood and humor, any significant mission events, and crew cohesion. Contacts were made with the control room team, managers, principal investigators, family members, and crewmembers. Contact with the crew was through two-way video meetings, telephone calls, and electronic mail. Family lunches also were held periodically during the mission. The psychological team served as a sounding board and information resource for all of these groups.

CONCLUSION

In conclusion, psychological countermeasures are a key aspect of any long-duration, human-rated test bed. They are most effective when they 1) are specifically designed for the demands of the target mission, and 2) address not only the crewmembers, but their families, key external personnel, and the wider organizational system that is fielding the test. Countermeasures act to increase the probability that the goals of the test will be met, and they do so by preventing difficulties and promoting performance readiness.

There is a direct, inverse relationship between the level of effort invested in the human aspects and the number of difficulties that arise during a confinement mission. Any reports from other such missions of difficulties with individual participants, within teams, between cultures, between external control personnel and internal participants, between participants and project managers, etc. can only be understood in light of the type, extent and quality of the interventions applied to prevent such problems. More often than not, when such problems occur, they can be traced back to the organization(s) that are fielding the mission and are responsible for implementing operational psychology countermeasures. How much effort should be invested? The answer to this depends upon how much difficulty and risk, and what kinds of difficulty and risk the organization is willing to accept.

The Advanced Human Life Support Enclosed System Study series was successful from both a technical and psychological point of view. The mission goals were attained, the crewmembers look back on their experience with a sense of satisfac-

tion and accomplishment, no significant mission management difficulties were encountered, and a step or two was taken forward on the road to the Moon and Mars. Early on, the project management recognized the importance of the human factor in the overall success of the series and was willing to invest in the pre-mission psychological activity necessary to ensure positive results.

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